PRELIMINARY DRAFT

(1)



# DEPARTMENT OF DEFENSE

# SOFTWARE MASTER PLAN

**February 9, 1990**




## •VOLUME I: PLAN OF ACTION•

Defense Acquisition Board (DAB)
Science and Technology (S&T) Committee
Software Working Group

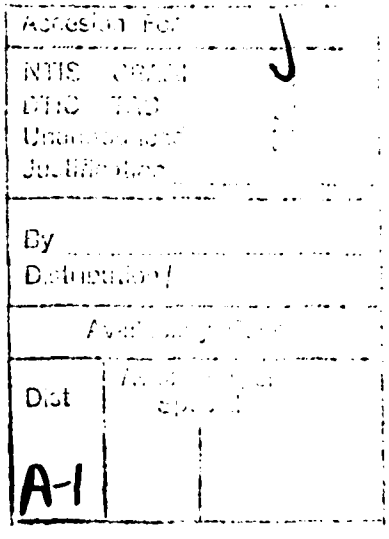


Chairman:
Dr. George P. Millburn

**This preliminary draft version is being released for public review and comment. The final draft version will be submitted for review and formal coordination by the S&T Committee and the DAB. The plan will then be submitted for final approval by the Secretary of Defense. It does not represent Department approval for any initiatives that are not presently authorized by the Secretary of Defense.**

*"Software plays a major role in today's weapon systems. The "smarts" of smart weapons are provided by software. Software is crucial to intelligence, communications, command and control. Software enables computerized systems for logistics, personnel, and finance. The chief "military software problem" is that we cannot get enough of it, soon enough, reliable enough, and cheap enough to meet the demands of weapon systems designers and users. Software provides a major component of U.S. war-fighting capability."*

Report of the Defense Science Board
Task Force on Military Software
September 1987

## EXECUTIVE SUMMARY

This DoD Software Master Plan was developed through the collaborative efforts of numerous offices and organizations within the Department of Defense (DoD) and under the auspices of the Defense Acquisition Board Science and Technology Committee. It provides a consolidated approach for addressing the challenges presented to the DoD today by the escalating development, utilization and cost of software in our defense systems. It identifies specific areas for improvement in research, development, test, deployment and maintenance of software in defense systems, including mission critical computer systems, automated information systems, scientific and engineering systems, and weapons systems. It also identifies feasible concrete actions to accomplish these improvements.

Throughout the development of the plan, the following underlying assumptions provided the basis for the strategy used in defining problem areas and proposing corrective actions:

- The principles of DoD's Total Quality Management initiative must guide the development of the plan;
- The scope of the plan should be limited to DoD issues;
- A plan for the future must be based upon a knowledge of today;
- Software demands and expectations will continue to increase;
- The DoD does not need another study on software problems;
- The plan must address all DoD software;
- Software must be viewed as part of a total system;
- System security, with emphasis on software, will be an increasing concern;
- Software engineering is not yet a true engineering discipline;
- The plan should not be a software primer; and
- Proposed actions must be explicit.

The means available to the DoD to effect the process and characteristics of software include: (a) software acquisition and life cycle management; (b) DoD software policies; (c) personnel; and (d) the software technology base and transition. For each of these means, related problem areas are addressed, goals are identified, and specific actions that are required to accomplish those goals are enumerated.

a. Software acquisition and life-cycle management: Many of the problems associated with DoD's acquisition and management of software sensitive systems can be attributed to: (1) the dichotomous oversight structure for computer resources within the DoD; and (2) the incompatibility between much of the guidance for defense management and acquisition and the emerging technologies for modern engineering concepts. The following goals were identified for improving DoD's acquisition and management of software:

   - Revise the DoD software acquisition management structure;
   - Increase management awareness and visibility of software issues and impacts on systems;
   - Enhance the life-cycle management process to introduce software improvements; and
   - Improve the contracting environment.

b. DoD software policies and standards: Current software policies, standards and guidance must be more consistent, more timely with respect to modern software engineering practices, less prone to misuse, more complete, and more readily enforced. The following goals were identified for improving these policies, standards and guidance:

   - Consolidate DoD policies for automated information systems and mission critical systems;
   - Update applicable DoD system policies and standards to reflect software impacts;
   - Update DoD software and related standards; and
   - Strengthen DoD advisory role in software export/import policy.

c. Personnel: A significant shortage of sufficiently qualified software personnel currently exists at all levels within the DoD. Consequently, actions must be taken to improve the ability of the DoD to attract and retain talented software professionals. The following goals were identified for increasing the number of qualified DoD software personnel:

   — Improve personnel policies to retain and develop qualified personnel; and
   — Improve education and training.

d. Software technology base and transition: The maintenance of a strong technology base requires sustaining the basic research activity, brokering technology transition relationships, advancing an infrastructure for engineering and prototyping, fostering an active and independent basic research community, and transferring the technology into use. The following goals were identified for enhancing the software technology base and improving technology transition:

   — Improve management of the DoD software technology base;
   — Increase the software technology base investment; and
   — Accelerate technology transition.

The following table provides a summary of the priority, funding and schedule for each of the actions identified within this plan as being necessary to accomplish the goals enumerated above. Actions are prioritized on a scale of #1 to #3, with #1 being most important. Actions are identified by the number/letter pair assigned in Chapters 2 through 5 and by a brief phrase, summarizing the action. Because it is not possible to capture the full meaning of each action in a single phrase, the reader is advised to refer to the full text associated with each action, provided in Chapters 2 through 5.

The action determined to be most significant in the implementation of this DoD Software Master Plan is the designation of an office by the Deputy Secretary of Defense to serve as a focal point within the DoD for software (Action #2-A). This office should have primary responsibility for identifying, managing, integrating and implementing software acquisition and life cycle management policy. Action #2-A also calls for the designation of a similar office within each of the DoD components.

## Action Summary, Prioritization, Schedule, and Funding

| Action Number and Summary | Pri. | FY91 | FY92 | FY93 | FY94 | FY95 |
|---|---|---|---|---|---|---|
| 2-A Designate office as SW focal point | 1 | | | | | |
| 2-B Ensure SW addressed within DAB structure | 1 | | | | | |
| 2-C Ensure TQM techniques used for SW | 2 | 1000K | 1000K | 1000K | 1000K | 1000K |
| 2-D Define SW risk management framework | 2 | 100K | | | | |
| 2-E Establish metric tool "Consumer's Union" | 3 | 1000K | 1000K | 1000K | 1000K | 1000K |
| 2-F Propose technology insertion projects | 3 | | | | | |
| 2-G Review acq. & contracting strategies for SW issues | 1 | | | | | |
| 2-H Initiate cases with FAR Council on SW issues | 1 | | | | | |
| 3-A Consolidate SW directives/policies/guidance | 1 | | | | | |
| 3-B Consolidate Ada policy and oversight | 1 | | | | | |
| 3-C Establish system policies to address SW support | 1 | | | | | |
| 3-D Review system acq. strategies for SW issues | 2 | | | | | |
| 3-E Update software and related standards | 2 | | | | | |
| 3-F Revise software export/import policy | 3 | | | | | |
| 4-A Define civilian SW career paths and salary incentives | 1 | | | | | |
| 4-B Define military SW career path to General/Flag rank | 1 | | | | | |
| 4-C Dev. service SW training plans leading to adv. degree | 1 | 2000K | 2000K | 2000K | 2000K | 2000K |
| 4-D Develop SW awareness and SW acq. mgt. courses | 2 | 300K | | | | |
| 4-E Develop accredited SE programs | 2 | 300K | 300K | | | |
| 4-F Develop DoD SE scholarship program | 2 | 50K | 500K | 500K | 500K | 500K |
| 4-G Integrate SW programs into DoD Joint Service Schools | 3 | | | | | |
| 4-H Establish SE educational requirements | 3 | | | | | |
| 5-A Use key principles to evaluate tech base managers | 1 | | | | | |
| 5-B Develop SW Technology Plan | 1 | | | | | |
| 5-C Develop plan for DoD SW repositories | 2 | 1000K | | | | |
| 5-D Establish SW Information Clearinghouse | 3 | 500K | 500K | 500K | 500K | 500K |
| 5-E Develop tech transition assessment process | 3 | 1000K | 1000K | | | |

## FOREWORD

During the past two decades, software has become the focus of functionality and flexibility in almost all Department of Defense (DoD) systems. While there have been several laudable efforts initiated within the Department to address software issues over the years, the DoD continues to encounter significant problems throughout the life cycle of its many systems.

On March 13, 1989, Dr. George P. Millburn, Chairman of the Defense Acquisition Board (DAB) Science and Technology (S&T) Committee, established a Software Working Group to define a program by which the DoD could: (1) provide increasing capabilities for existing and emerging systems; and (2) reduce the costs associated with the development and life cycle maintenance of software. In order to ensure a consolidated DoD approach to this effort, membership on the Software Working Group was expanded to include representatives from all DoD organizations in which software was a major area of concern. As a result, the Software Working Group consisted of representatives from the following organizations:

- Office of Under Secretary of Defense (Acquisition):
  - Office of Deputy Under Secretary of Defense (Industrial and International Programs)
  - Office of Director, Program Integration
  - Office of Assistant Secretary of Defense (Production and Logistics)
  - Office of Deputy Director of Defense Research and Engineering (Research and Advanced Technology)
  - Office of Deputy Director of Defense Research and Engineering (Strategic and Theatre Nuclear Forces)
  - Office of Deputy Director of Defense Research and Engineering (Tactical Warfare Programs)
  - Office of Deputy Director of Defense Research and Engineering (Test and Evaluation)
- Office of Assistant Secretary of Defense (Command, Control, Communications and Intelligence)
- Office of Assistant Secretary of Defense (Program Analysis and Evaluation)
- Office of DoD Comptroller
- Office of Director, Operational Test and Evaluation
- Joint Staff
- Office of Assistant Secretary of the Army (Research, Development and Acquisition)
- Office of Assistant Secretary of the Navy (Research, Development and Acquisition)
- Office of Assistant Secretary of the Air Force (Acquisition)
- Defense Advanced Research Projects Agency
- Strategic Defense Initiative Organization
- Defense Communications Agency
- National Security Agency

The original intent of the Software Working Group was to develop a DoD Software "Technology" Plan. However, the majority of members soon agreed that such a limitation of scope would not address many of the software problems being encountered within the Department today that are the result of nontechnical factors. As noted in [ZRACKET88]:

> "Better management techniques applied to software-intensive projects will increase productivity and lower risk in the near term. Management changes can cause improvements because the state-of-the-practice is far behind the state-of-the-art. Once that gain has been made, further substantial progress in software productivity and quality must come from future technology improvement."

The DoD Software Master Plan represents the collective efforts of the Software Working Group members, as well as the many individuals within the DoD who worked so diligently to review and provide constructive feedback on the various iterations of the document. All contributors were constrained by a very rigid time schedule, driven by the need to provide: (1) a very proactive approach to addressing the problems during a time of review and change within the Department

as a result of the Defense Management Report [OSD89]; and (2) a timely and realistic plan that was viable for public scrutiny.

Particular recognition and appreciation is extended to the representatives of the following organizations, who provided additional inputs to the Software Working Group for consideration in development of the plan:

- Aerospace Industries Association of America (AIA)
- American Institute of Astronautics & Aeronautics (AIAA)
- American National Standards Institute (ANSI)
- American Society for Quality Control (ASQC)
- Armed Forces Communications & Electronics Association (AFCEA)
- Association for Computing Machinery (ACM)
- Data Processing Management Association (DPMA)
- Electronics Industries Association (EIA)
- Institute for Electrical & Electronic Engineers (IEEE)
- National Security Industrial Association (NSIA)
- Society of Automotive Engineers (SAE)
- X/OPEN

This document is provided in two volumes. Volume I (consisting of Chapters 1 through 6) provides the basic plan of action for the DoD. It is organized around the primary means by which the DoD can effect the process and characteristics of software: management, policy, personnel, and technology. Each of these is treated individually in Chapters 2 through 5 which provide detailed discussion and rationale for specific actions that are required within the DoD. Each action identifies one or more individuals, offices, or components to carry out that action, as well as a priority and an estimate of time and cost required. A start date of fiscal year 1991 is used as the basis for scheduling. Chapter 6 provides a summary, priority, funding and schedule for each of the required actions identified in Chapters 2 through 5.

Volume II (consisting of Annexes A through G) provides background information gathered from the contributing DoD components during the development of this plan. It represents the current status of various aspects of the DoD with regard to software. Annex A provides a description of the current software management roles of offices and organizations within the DoD. Annex B provides a listing and description of the many existing DoD policies, standards and guidance documents regarding software and systems. Annex C provides a description of current software research and development efforts within the DoD. Annex D provides a description of a number of cross-cutting issues of critical importance to the DoD that are not easily discussed in the framework of Volume I. Annex E provides a summary review of twelve previous studies on software issues and identifies actions that have been taken thus far within the DoD as a result (direct or indirect) of such software studies. The material provided by these Annexes was instrumental in the identification of issues and formulation of corrective actions enumerated within Volume I. Supplemental Annexes F and G provide a list of references and acronyms, respectively. Volume II is germane to understanding the factors considered during the development of the basic plan provided in Volume I.

TABLE OF CONTENTS

# 1. INTRODUCTION

## 1.1 Purpose

The Department of Defense (DoD) Software Master Plan documents a consolidated DoD approach to addressing the challenges presented by the escalating development, utilization and cost of software in our defense systems. It identifies specific areas for improvement in research, development, test, deployment and maintenance of software in defense systems, including mission critical computer systems, automated information systems, scientific and engineering systems, and weapons systems. It also identifies feasible concrete actions to accomplish these improvements.

## 1.2 Background

Software is defined to be those computer programs, procedures, rules, and associated documentation and data, pertaining to the operation of a computer system. In the past several decades, software technology has played an increasingly larger role in maintaining our military superiority. In fact, the DoD Critical Technologies Plan [DOD89] identifies software producibility as one of the most critical technologies impacting the DoD today. From weapons systems to payroll systems and from inventory management to intelligence activities, there is a steadily increasing reliance on software technology across all aspects of defense activities. There are several major impacts resulting from this increasing reliance:

1. Organizational Impact: The increasing automation of capabilities throughout the DoD is fundamentally changing the character of the DoD and the missions of its individual organizations. Automation is not simply the process of replacing existing equipment and weapons with automated versions but also includes the process of enabling capabilities that were previously impossible. Because of technological advances, high level commanders, including the President, now expect to have information to survey individual situations and to direct sophisticated operations remotely. Such a capability creates new mission relationships and pervasive interoperability and security demands. Thus, the introduction of new capabilities through automation creates organizational changes which then require additional new capabilities.

2. System Requirements Impact: Increasing computer technology capabilities have led to growing expectations and demands for system functionality. These, in turn, have led to expanding software requirements. These requirements have evolved from: (1) the use of advancing technologies, including processing capabilities, by system designers to create more complex systems; and (2) the allocation of a larger percentage of system complexity to software in order to maximize system flexibility. This combination of trends was noted in [ZRACKET88]:

   > "The size and complexity of this software has been growing exponentially, because designers choose to implement needs of the increased functional complexity of these systems in software"

   Since the allocation of system complexity to software is increasing, a large percentage of system problems are often perceived as software problems. Further, the size and cost of designing, creating, and deploying this software is increasing with its complexity. As noted in [Tenenbaum87]:

   > "Growth in the numbers, speed, and power of the embedded hardware has increased the length and complexity of the software to run the computers. The F-16D has 236,000 lines of code... It is estimated that the ATF (Advanced Tactical Fighter) will require as many as seven million lines of code..."

   Further, even after systems are deployed, the DoD must possess the critical capabilities to maintain and evolve the software in these complex systems throughout the system's life cycle.

3. System Acquisition Impact: The contracting and management mechanisms, data rights options, and support approaches are all being impacted by the increase in software demand and the introduction of commercial off-the-shelf (COTS) software into the military domain. As stated in [HOUSE89]:

> "Computer software, which is now a major cost item in many procurements, is not immune from traditional procurement problems such as delay, cost overruns and poor performance. Worse, the procurement system as presently structured does not take into account the special needs of computer software systems and can compromise effective software development from the start."

4. System Life-Cycle Impact: In addition to the direct impact of software as part of a system, software tools are beginning to play a major role in the support of the system design, development, test, evaluation, operations, and maintenance processes. Software tools now available in limited domains support the specification and immediate evaluation of a system design, thus supporting the iterative refinement critical to achieving optimal designs. Separately developed and managed systems must be combined to satisfy operational requirements. Use of automated tools will be needed to isolate and resolve problems and reliably make changes in these integrated environments.

5. Software Implementation Impact: The increased demand for complex software, the need to take advantage of dynamic enhancements in computer hardware technology, and the desire for competitive procurements are intrinsic to the DoD environment. As a result, DoD must protect its investment in software across different hardware platforms while amortizing its cost over the largest possible user base. This will result in the increased importance of software that is reusable, portable, and built on COTS products which takes advantage of standards in an open systems environment.

6. Software Security Impact: While computer security is emerging as a critical issue in defense systems, progress in the area has not kept pace with needs. DoD's increasing reliance on software makes it imperative that the software not only act as specified, but is also not easily subverted or compromised.

The DoD requires an effective way to focus management attention on, and deal with, software issues. It must recognize that the root cause is not simply software oriented, but a direct result of deficiencies within the overall DoD system. In order to address these deficiencies, specific actions must be taken in the following areas: (1) software acquisition and life cycle management; (2) DoD software policies, standards, and guidance; (3) personnel; and (4) the software technology base and software technology transition. This plan addresses each one of these areas and identifies specific actions for improvement. However, there are several highly visible and critical issues that must be addressed across these areas. They include the software process, software reuse, high assurance and secure/trusted software, real-time software, and parallel and distributed software. Annex D provides a high-level review of these cross-cutting issues as background and motivation for the required actions of Volume I.

## 1.3 Assumptions

Throughout the development of this plan, there were several underlying assumptions upon which the strategy for defining problem areas and proposing corrective actions was based. These assumptions are summarized in the following sections.

### 1.3.1 The Principles Of DoD's Total Quality Management Initiative Must Guide The Development Of The Plan

Quality requires a commitment to continuous improvement by all DoD personnel. The current DoD Total Quality Management (TQM) initiative emphasizes the importance of teamwork, improved communications DoD-wide, managers' participation in the policy making process, innovation, integrity and accountability. The development of the DoD Software Master Plan must be guided by these same basic principles. However, the application of these principles in

order to effect change in the acquisition process will encounter several problems. As noted in [BETTI89]:

> I anticipate four problems in effecting change.
>
> First of all, impatience. We all have a predilection for quick fixes, a need to see immediate results. But as Secretary of Defense Dick Cheney has said, there is no silver bullet for success. Reform will be a long, slow, arduous process.
>
> The second problem will be resistance. Defenders of the status quo are always threatened by the prospect of change. It will take consistency, constancy of purpose, tenacity and perseverance to bring about the needed reforms.
>
> Third, parochialism. Everyone who has a stake in the process—DoD, Congress and industry—must be committed to optimizing the overall process, even when a specific solution may not be optimum from their particular viewpoint.
>
> Fourth, superficiality. We must differentiate between treating the symptoms and treating the root causes. Above all, we must be careful not to mistake activity for accomplishment.

These same problems will be faced by those within the DoD who attempt to effect change regarding software.

### 1.3.2 The Scope Of The Plan Should Be Limited To DoD Issues

While issues associated with software certainly impact other federal departments and agencies, as well as the industrial, academic and international sectors, the DoD must first develop its own Master Plan to deal with these issues within the Department. A consolidated DoD Software Master Plan can then be considered as representative of the Department in the development of a future federal or national software initiative.

Limiting the scope to the DoD does not, however, preclude the involvement of non-DoD personnel in its development. Drafts of the document should be widely distributed, and feedback from the community should be strongly encouraged.

### 1.3.3 A Plan For The Future Must Be Based Upon A Knowledge Of Today

A plan that will ultimately impact almost every sector of the defense community must be based upon a clear assessment of the problem areas as they exist today. That assessment can only be accomplished following a comprehensive review of the major areas of interest and impact.

Recommended actions regarding software related organizational and managerial reform cannot be articulated without an understanding of the current organizational structure and managerial responsibilities. Recommended actions regarding policy changes and reform cannot be defined without an appreciation for the myriad (and often conflicting) guidance currently imposed within the DoD. Recommended actions regarding technology based initiatives cannot be proposed unless current technological requirements and/or voids can be demonstrated. This primary assumption was the basis for the development of the background information included within Annexes A, B, C and D.

### 1.3.4 Software Demands And Expectations Will Continue To Increase

The environment in which the DoD must operate is constantly changing. Many of these changes will have an impact on software demands and expectations:

- Eastern European and Third World trends will lead to a proliferation of less predictable threats to challenge DoD. Coping with these threats requires more flexible, interoperable, secure, and reliable $C^3I$, which is software intensive.
- Reduced DoD budgets will increase automation needs to reduce inefficiencies and personnel costs, thus creating further demands on software. Affordability will drive DoD toward

common modular components, with flexible software support.

- A reduced DoD worldwide presence increases the importance of rapid mobilization and deployment, which rely critically on software planning and logistics support.
- Reduced DoD manpower levels imply the need for more automated and semiautomated systems to maintain force effectiveness.
- Increased networking of DoD systems places escalating strains on computer and software security capabilities.

### 1.3.5 The DoD Does Not Need Another Study On Software Problems

In general, the problems associated with software within the DoD have been recognized and addressed for many years through various studies, often sponsored by the DoD. These studies, accomplished by highly knowledgeable and credible individuals and organizations, provide a basis from which specific actions can be identified. DoD resources should not be expended to repeat the effort of conducting a study on the problems associated with software within the DoD. Resources should instead be allocated to the task of capitalizing on those studies by reviewing their respective assessments, conclusions, and recommendations as a precursor to the identification of specific actions to be accomplished within the DoD. This assumption was the basis for the development of background information in Annex E.

### 1.3.6 The Plan Must Address All DoD Software

Because software problems within the DoD are pervasive across the Department, and not specific to one particular class of defense system, the plan should not be restricted to discussing only mission critical computer resources, automated information systems (AIS), scientific and engineering systems, or weapons systems. For the primary purpose of addressing all such systems, the term "software sensitive" is used throughout this plan.

### 1.3.7 Software Must Be Viewed As Part Of A Total System

Although software is perceived as distinct from hardware, it does not stand alone and must, therefore, be viewed as part of a total system. The software engineering process is part of the overall systems engineering process which is, in turn, part of the systems acquisition process. As such, any initiatives to improve the software process must be consistent with efforts in the parent process in order to realize effective change.

Software and hardware are components of an overall system, but there are unique characteristics associated with software that preclude its being developed and maintained in a manner that may be satisfactory for hardware. Although there exist various forms of representation for software (e.g., text, flow diagrams, etc.), it is not a physical substance. Software has no process corresponding to the hardware manufacturing process. For much of defense software, there currently exists little capability to capitalize on initial investment, as one would do with hardware, through quantity of production and sales. Although almost every software program is unique, there does exist the potential for reuse of portions of software previously designed. The challenge remains to turn that potential into reality.

While measurable tolerances may exist for hardware, there are no such tolerances associated with software. A single software error or an erroneous assumption in the initial specification could potentially cause a system to fail, with possible life threatening consequences. Thus, the standards for measuring success of software are far more stringent and unforgiving than any associated with hardware. This is made even more difficult by the physical inability to test all aspects of a system and the lack of a proven method to forecast the requirements for post-deployment software support (PDSS).

### 1.3.8 System Security, With Emphasis On Software, Will Be An Increasing Concern

Most DoD software, whether it be part of mission critical or automated information systems, requires some level of security. DoD system acquisition managers must address this issue by integrating computer security into their systems. One of the major challenges for DoD is to develop a mindset that recognizes computer security as an integral part of every system acquisition.

### 1.3.9 Software Engineering Is Not Yet A True Engineering Discipline

The development of software is largely a human activity, subject to human behavior and individual assumptions. The development of a software engineering discipline based on mathematical principles and natural physical laws is still in its earliest stages. Although there is now considerable accumulated knowledge and experience that can be applied to future systems, this knowledge still falls short of scientific and engineering precision.

### 1.3.10 The Plan Should Not Be A Software Primer

The plan should articulate a course of action for the DoD and provide the appropriate rationale for doing so. However, the efficacy of the resultant document could be reduced if its contents were diluted with tutorial information. Every effort should be made to justify proposed required actions with a minimum of tutorial information and software specific technical jargon.

### 1.3.11 Proposed Actions Must Be Explicit

A primary deficiency of many previous software studies accomplished for the DoD was that the recommendations were too vague or ambiguous. For that reason, the plan must be explicit in specifying the priority of the action, which office(s) should undertake the action, how long that particular action is expected to take, and what cost is associated with that particular action.

# 2. SOFTWARE ACQUISITION AND LIFE CYCLE MANAGEMENT

**ISSUE:** *Fragmented oversight structure and guidance inhibit utilization of modern software technologies by the DoD.*

Problems associated with DoD's acquisition and management of software sensitive systems can be attributed to two factors. First, the dichotomous oversight structure for computer resources within DoD has impeded the transfer of technology and experiences among defense systems. The DoD has a parallel series of directives that are consistent with the legislative requirements of the Brooks Act and Nunn-Warner Amendment. Separate classification and management of defense systems along these lines assumes that a single acquisition oversight structure cannot accommodate all types of defense software systems. Second, defense guidance regarding computer resources has not kept pace with technology advances. The studies listed in Annex E suggest that in order to correct the problems associated with DoD's computer resources, fundamental changes must occur in DoD management.

To alleviate these problems, a proactive acquisition and life-cycle management process must be established by: (1) revising the current DoD software acquisition management structure; (2) increasing management awareness and visibility into the software aspects of systems; (3) enhancing the life-cycle management process to introduce software improvements; and (4) improving the contracting environment.

## 2.1 GOAL: Revise DoD Software Acquisition Management Structure

Specific DoD guidance for management oversight of software sensitive systems has evolved as a result of the Brooks Act and the Nunn-Warner Amendment (exemptions) to that Act. Though not required by law, the DoD has traditionally separated its management oversight of software sensitive systems. With certain exceptions, oversight of AIS (Brooks Act) is currently under the purview of DoD Comptroller, who serves as DoD's senior Information Resources Management official; and oversight responsibility for mission critical systems, including weapons systems (Nunn-Warner Amendment) is currently under the purview of the Under Secretary of Defense for Acquisition, who is the Defense Acquisition Executive. Guidelines for AIS software sensitive systems are enumerated in the DoD 79xx series of directives and instructions, while mission-critical systems are administered under the auspices of the DoD 5000 series of directives and instructions. Scientific and engineering software may be managed by either series, depending on the unique circumstances of that software.

The current dual oversight process for software sensitive systems is inadequate for modern defense systems and has resulted in duplicative, conflicting and artificially fragmented acquisition guidance, policies and oversight for software sensitive systems. Continuation of this approach can lead to confusion and misapplication of sound management principles that contribute to reducing risks associated with development and acquisition of software sensitive systems.

The DoD must ensure that: (1) appropriate and adequate management attention is focused on the software aspects of all defense acquisitions; (2) proper vehicles (policies, guidelines, regulations) are in place which accommodate the software characteristics and are in the best interests of both the DoD and industry; and (3) that continuing education regarding the proper use of such vehicles is available to all DoD personnel. This requires that a single advocate, devoted to the problems associated with software sensitive systems–including all AIS, mission-critical, weapons, and scientific and engineering systems–be identified within DoD. Existing guidance needs to be simplified and reorganized to establish a unified approach for development and acquisition of software sensitive systems.

**REQUIRED ACTIONS:**

**2-A Designate an office with primary responsibility for identifying, managing, integrating and implementing software acquisition and life-cycle management policy. This office will have cognizance over all DoD software. This office should also have primary responsibility for ensuring the implementation of the remaining actions enumerated within this plan, as *decided by the Deputy Secretary* of Defense. DoD components should take similar actions to designate such an office within their respective organizations.**

**OPR: Deputy Secretary of Defense**
**Estimated time to accomplish: 3 - 6 months**
**Estimated cost: Not applicable**
**Priority: 1**

**2-B Revise applicable policy directives and instructions to ensure that software considerations are adequately addressed within the Defense Acquisition Board (DAB) structure.**

**OPR: OUSD(A)**
**Estimated time to accomplish: 6-12 months**
**Estimated cost: No direct costs**
**Priority: 1**

## 2.2 GOAL: Increase Management Awareness And Visibility Of Software Issues And Impacts On Systems

Compounding the problems related to oversight of software sensitive systems is the reticence of many senior acquisition officials to challenge and/or question computer and software aspects of systems acquisition. This reticence is often caused by communication difficulties between management and the software community. These problems limit the ability to identify issues/concerns and to develop recommendations regarding computer and software facets of defense acquisition programs.

Visibility into system cost, schedule, and performance aspects is required for all acquisitions. The software process must provide acquisition and operational managers with sufficient data to facilitate assessments of software costs, schedule and performance, and the relationship to (and impact on) the respective system level assessments. A development process with effective control can support decisions concerning new commitments with more predictable results, thereby enabling more effective management and risk control. Also, estimation and control techniques enable effective balancing among trade-off items, such as degree of assurance, developer capitalization and use of conventionalized designs, in meeting mission objectives.

Software cost estimates in DoD programs have often been the cause of contract overruns in DoD systems acquisition. Better visibility of true software costs in the acquisition process will result if DoD improves the collection of basic software cost data from contractors, and monitors costs with up-to-date software cost estimating procedures. Cost estimation that does not address software support can result in low-cost initial developments, but with high post-deployment costs. Hence, cost estimation must include PDSS and include benefits gained through the use of conventionalized architectures and interfaces, including use of reusable and COTS components.

Projects must be managed with attention to risks; i.e., their measurement, control, and reduction, including the software components of system risk. In practice, system and software managers are usually engaged in crisis management and are unable to focus on primary risk sources. The principal challenge is to develop the means to begin analysis, management and reduction of risk during requirements definition. This requires that system managers recognize and control software risks as a fundamental element of system risk. It also requires that software mangers have experience in risk mangement techniques.

**2-C Ensure Total Quality Management (TQM) techniques for software life cycle management are incorporated into both program management and contracts for modern software sensitive systems to support this action. The following should be addressed:**

- **— Initiate a calibration program to provide for consistent application and interpretation of software metrics and their application domains.**
- **— Promulgate a generic set of visibility tools for management use that provide insight into software products and processes, including cost, schedule, and performance parameters.**
- **— Work with the OSD Cost Analysis Improvement Group to provide a set of recommendations to assure improvements in the effective use of and collection of basic software cost data.**

**OPR: OUSD(A)**
**Estimated time to accomplish: Continuous (Baseline in 24 months)**
**Estimated cost: $1M per year**
**Priority: 2**

**2-D Develop and promulgate software risk management techniques for identifying, assessing and controlling software risks, e.g. performance, security, cost, and schedule, throughout the system life cycle.**

**OPR: OUSD(A)**
**Estimated time to accomplish: 12 months to develop**
**Estimated cost: $ 100K**
**Priority: 2**

**2-E Establish a DoD software "Consumers Union" to provide unbiased and independent evaluations of commercial software measurement and visibility tools that can potentially be used by the DoD.**

**OPR: OUSD(A)**
**Estimated time to accomplish: 12 months to propose and select**
**Estimated cost: $1M per year to operate facility**
**Priority: 3**

## 2.3 GOAL: Enhance The Life-Cycle Management Process (Development And Post Deployment Software Support) To Introduce Software Improvements

Long-lived software sensitive systems are often plagued by insufficient memory, insufficient processor speed, a software design that is not up to current practice, an archaic programming language, and an increasing complexity of code as the system ages. These constraints and factors result in substantial costs for post deployment software support.

Development approaches that address life-cycle risks and mid-life upgrades of existing hardware and/or software could ameliorate these problems. An investment in either approach could result in sufficient benefit, including enhanced productivity in software support, to make the investment economically sound. The investment could be:

a. Advanced technology oriented to remove hardware constraints;

b. Upgrade to current technology, which could require software recoding to improve its structure, memory usage, etc., or redesign into more modern operating environment; or

c. A mix which could involve both of the above improvements.

**REQUIRED ACTIONS:**

**2-F Propose projects to demonstrate strategies for accommodating technology insertion throughout the software life cycle. Strategies include but are not limited to a mix of rapid prototyping, shadow projects and mid-life upgrade projects. These proposals will be part of the DoD Software Technology Plan described in Chapter 5.**

**OPR: OUSD(A)**
**Estimated time: 6 months**
**Estimated cost: No direct costs**
**Priority: 3**

## 2.4 GOAL: Improve The Contracting Environment

DoD policies and regulations related to software, particularly in the area of acquisition, often conflict with practices acceptable to private industry. DoD acquisitions often concentrate on the hardware aspects of systems, with little concern for impacts associated with software. The hardware-premised acquisition process is established to reduce costs associated with production of the system (hardware/weapon). This approach is contrary to the software development process where costs are attributable to the design, development, testing, and post deployment support of the system, rather than to the production of the system. Contractors desire more rights to software they have developed and incentives to use existing or "reusable" software in systems.

The DoD must identify and correct those procurement procedures related to contractual incentives, software reuse, and capitalization, which contribute to an erosion of the DoD software industrial base. Actions related to this include revising software procurement procedures so as to strengthen the industrial base, contributing to an enhanced competition, supporting a "best value" acquisition strategy, and accommodating commercial interests.

Some aspects of defense procurement procedures, specifically those related to reusability, work breakdown levels, Federal Acquisition Regulation (FAR) procedures for capitalization of software tools, software copyright and data right procedures, have contributed to what many industry representatives feel is a marginal business environment. As a result, commercial firms have made conscious decisions to exclude DoD efforts from their business base. A modified contracting process for software sensitive systems which focuses on the use of contractual incentives, modified claims to software data rights, and increased use of licensing agreements and copyrights can mitigate the current situation.

While many involved with systems acquisition are comfortable in applying and tailoring existing contract mechanisms, e.g., standards, specifications, contract type, statement of work requirements, etc., for hardware, the same is not true for aspects of the system's software. A similar problem exists for monitoring and administrative support during contract execution. As systems become increasingly software sensitive, there is an ongoing need to refine and improve current contracting vehicles and methods to monitor contracts. Both defense and commercial interests are served by integrating awareness of computer and software oriented concerns into the contracting environment, while capitalizing on experimental application of prevailing commercial practices.

**REQUIRED ACTIONS:**

**2-G Review acquisition and contracting strategies to ensure that software considerations are adequately addressed in realistic cost, schedule, and performance terms.**

**OPR: OUSD(A)**
**Estimated time to accomplish: Continuous**
**Estimated cost: No direct costs**
**Priority: 1**

**2-H Initiate cases with the FAR Council, as appropriate, to address software-related issues including the following:**

- **— Redefinition of the term "software" and establishment of software as a contractually deliverable item;**
- **— Intellectual property protections;**
- **— Capitalization of software products;**

— **Reusable, existing, and COTS software that affect system performance, interoperability, and logistics; and**
— **Technology insertion mechanisms.**

**OPR: OUSD(A)**
**Estimated time: 6 months**
**Estimated cost: No direct costs**
**Priority: 1**

# 3. DoD SOFTWARE POLICIES AND STANDARDS

**ISSUE:** *Hardware oriented DoD policies, standards, and guidance are not effective in managing modern software sensitive environments.*

Existing DoD policy, standards and guidance documents regarding software and systems are identified in Annex B. DoD software studies (Annex E) identify the need for revision of government software policies. While these studies have concentrated on weapon system or mission critical software applications, the findings are often applicable to information systems. It is imperative that current software policies, standards and guidance be made more consistent, more timely with respect to modern software practices, less prone to misuse, more complete, and more readily enforced. A major objective of the DoD Software Master Plan is to identify opportunities for improving the DoD policies, standards and guidance. This requires: (1) consolidating the DoD policies for automated information systems and mission critical systems; (2) updating applicable DoD system policies and standards to reflect software impacts; (3) updating DoD software and related standards; and (4) strengthening DoD advisory role in software export/import policy.

## 3.1 GOAL: Consolidate DoD Policies For Automated Information Systems And Mission Critical Systems

Existing acquisition and management policies focus primarily on computer hardware. Although there are differences in procurement law for AIS and mission critical systems, there are large areas of commonality between the two communities that would benefit from consistent policy. A need exists for consistent, current and rational policy for computer resource acquisition and planning that also addresses the advances made in software management and technology.

Consolidated policy should integrate existing policy to the maximum extent possible and provide a baseline for implementing further policies and practices in response to top-level acquisition management and policy directions. As a result of the Defense Management Report (DMR), AISs are now under the cognizance of the DAB. A natural outgrowth of, and a derived requirement from, the DMR is the need for consistent software policy. New consolidated policy, and its associated documents, should emphasize the following major policy elements:

a. A single DoD focal point for software acquisition policy to ensure implementation, follow-through, and enforcement;

b. Mandatory software training programs for upper level managers;

c. Tracking of software costs throughout a system life cycle;

d. Development and continual update of a Computer Resources Life-Cycle Management Plan to be certified by the Service Acquisition Executive and then submitted to the DAB as part of the required documentation to support the Milestone I decision;

e. Early identification of software related risks and risk-management strategies, with an emphasis on early resolution of risk items;

f. Mechanisms to promote reuse of system architectures and designs, and, where appropriate, software components;

g. Mechanisms for user involvement in software and system development;

h. Incentives based on life-cycle performance;

i. Use of software process maturity assessment of an organization as a source selection criterion;

j. Software documentation requirements to address operational needs; and

k. Criteria for mid-life re-engineering of existing software systems.

Policies should be as technology independent as practical in order to promote:

a. Adoption of modern development and support process models. Process models should not be so rigidly defined as to inhibit use of different/improved models.

b. Incentives for development of effectively reusable software assets, including systems architectures and interfaces.

c. Tailoring of software documentation requirements to those necessary for cost effective operational support. Policy must allow for modification of rights-in-data provisions, use of electronic media deliverables containing system documentation object bases, and other steps required to enable preservation and ease of access to the necessary and sufficient design information needed to maintain/enhance software and documentation in the post deployment software support environment.

d. Contractor capitalization. Incentives for contractors to capitalize on their investments can increase their productivity and can also reduce life-cycle costs. The development and use of modern practices and tools provides the means to address many of the challenges related to risk- reduction, reuse, and life-cycle cost reduction.

Policies should support advancing technology. Many current government software policies are based on outdated approaches to the software development process. Policies need to enable appropriate use of rapid prototyping, reusable and COTS software, fourth generation languages, incremental and evolutionary software development approaches, software risk management, domain-specific software architectures, object-oriented software design and development, and other approaches based on new technologies, as they emerge.

New approaches to the software process, while often promising significant improvements in productivity and quality, can often, in their initial uses, entail significant increases in risk for software managers because of immaturity of supporting technology or management practices. Attaining sufficient maturity, however, usually requires full-scale prior use.

The policy challenge, therefore, is to provide the means to reduce the risks associated with adoption of new approaches, and, thus, to stimulate the use of more cost-effective approaches. Many existing policies were developed in order to accelerate transitions from the practices and technology of the 1960s to the practices and technology of the 1970s. Where these policies succeeded in promoting modern and efficient practices five or ten years ago, they are now, in some cases, impeding progress. Policies should recognize explicitly that technological capability is continually improving, and that regular policy adjustments are required.

**REQUIRED ACTIONS:**

**3-A Update, consolidate, and promulgate consistent DoD policy and guidance for the acquisition and life-cycle management of software sensitive systems.**

**OPR: OUSD(A)**
**Estimated time to accomplish: 12 months**
**Estimated cost: No direct costs**
**Priority: 1**

**3-B Consolidate all policy and oversight responsibilities with regard to Ada, emphasize the mandate to use Ada and enforce that mandate.**

**OPR: OUSD(A)**
**Estimated time to accomplish: 3 months**
**Estimated cost: No direct costs**
**Priority: 1**

## 3.2 GOAL: Update Applicable DoD System Policies And Standards To Reflect Software Impacts

Software is an essential element of modern defense systems. Accordingly, it is imperative that system policies and standards: (1) recognize the impacts of software on the acquisition of systems; and (2) specify strategies for more efficient software acquisition. In addition, policies and standards, whether system or software unique, should be consistent in their support of DoD system acquisition objectives. Examples of system standards that currently inadequately support desired DoD software policy objectives include: MIL-STD-499 (system engineering); MIL-STD-785B (reliability); MIL-STD-881A (work breakdown structure and cost capturization); MIL-STD-1388 (logistics support); and MIL-STD-1521B (reviews and audits). DoD system level policies must also recognize mechanisms for the development of software systems that can satisfy certain specific system level requirements provisions, such as cost, reliability, performance, security and safety properties, with very high levels of confidence.

The largest share of software costs are incurred after deployment in operations. The largest cost driver is software changes not anticipated in initial design, additional interfaces, human factor adjustments, and unforeseen performance demands. Increased management attention is required to create an effective interaction between system engineering, technology base, and operating logistics environments. Emerging software engineering practices and support tool environments show promise in expediting changes while retaining reliability. The tool sets must be designed to support the operational environment and overall integrated logistics posture throughout the entire life cycle.

**REQUIRED ACTIONS:**

**3-C Establish and promulgate DoD system engineering and logistics policies that promote the integration and application of development and support activities throughout the system's life cycle. These policies must address all relevant functional disciplines, including software engineering, to ensure that the system is responsive to user requirements.**

**OPR: OUSD(A)**
**Estimated time to accomplish: 12 months**
**Estimated cost: No direct costs**
**Priority: 1**

**3-D Identify and initiate appropriate actions for those DoD system level acquisition standards that require modification to address software considerations; and promote incorporation of technological advances in the acquisition and support processes.**

**OPR: OUSD(A)**
**Estimated time to accomplish: 18 months**
**Estimated cost: No direct costs**
**Priority: 2**

## 3.3 GOAL: Update DoD Software And Related Standards

As noted in Annex B, there are a large number of existing software unique standards, many of which are over five years old, although a five year review cycle is an integral part of the standardization process. The review cycle allows sufficient contractual experience to be gained so as to identify, capture and prepare required modifications. As experience is obtained, it is necessary to ensure that standards, e.g., DOD-STD-2167A (software development) and DOD-STD-2168 (software quality), and associated handbooks support DoD policy objectives and promote incorporation of technological advances into the acquisition and support processes. Data standards are equally significant for assuring standard software development and interoperability of software applications.

**REQUIRED ACTIONS:**

**3-E Develop and recommend pertinent modifications to software and related standards and work with the offices of primary responsibility (normally Service organizations) to ensure the prompt incorporation of required changes. Participate in commercial standards activities, initiating them when appropriate, to avoid development of DoD specific standards.**

**OPR: OUSD(A)**
**Estimated time to accomplish: Continuous**
**Estimated cost: No direct costs**
**Priority: 2**

## 3.4 GOAL: Strengthen DoD Advisory Role In Software Export/Import Policy

A conflict exists between the DoD needs to: (1) develop a strong industrial software base; and (2) ensure national security. Software is a critical component of our defense systems. Uncontrolled exportation of software can inadvertently compromise national security through the release of critical technology. Unexamined importation of software and supporting hardware (i.e. chip sets) renders the DoD vulnerable to deliberate subversion, as well as lack of industrial based support during times of conflict. It is essential for national security to sustain a strong U.S. software industry.

The DoD must address both sides of these conflicting issues. The DoD must protect critical software technologies and support environments. DoD contractual and security procedures need to be updated and official positions established for technology transfer. In an advisory role, the DoD must take an active and aggressive stance in promoting U.S intellectual property rights through the objectives of the General Agreement on Tariffs and Trade, the World Intellectual Property Organization, and CoCom (Cooperation Committee). The DoD must also work with the European community as it transitions to "Europe 1992."

**REQUIRED ACTIONS:**

**3-F Recommend policy that addresses DoD interests in security, foreign trade barriers and tariffs, intellectual property protection, and the importance of open markets and reciprocal trade strategies.**

**OPR: ODUSD(I&IP)**
**Estimated time to accomplish: Continuous**
**Estimated cost: No direct costs**
**Priority: 3**

# 4. PERSONNEL

**ISSUE:** *A significant shortage of sufficiently qualified software personnel currently exists at all levels within the DoD.*

In order to strengthen the capabilities of the software workforce at all levels within the DoD, actions must be taken to improve the ability of the DoD to attract and retain talented software professionals. There are a number of reasons why the DoD must maintain an internal base of software expertise:

a. The DoD must have internal expertise in order to effectively formulate specifications for software acquisitions.

b. The DoD must retain the ability to represent, as a customer, its own interests since they are often at variance with the interests of the producers.

c. DoD policies, standards, and guidelines, require continual revision and update. Personnel involved in the development of these standards and policies must understand the technology.

d. Program managers and internal DoD life-cycle support personnel must be able to effectively represent the DoD interest and make programmatic decisions in a technically informed way. The ability to assess risks associated with adoption of new approaches to software development derives from technical understanding. One of the key inhibitors to adoption of modern technology in DoD acquisitions is conservative decision-making by acquisition and support personnel who have insufficient technical background to effectively judge tradeoffs between risks and benefits.

A major objective of the DoD Software Master Plan is to identify opportunities to strengthen the capabilities of the DoD software workforce. This requires: (1) improving personnel policies to retain and develop qualified personnel; and (2) improving education and training.

## 4.1 GOAL: Improve Personnel Policies To Retain And Develop Qualified Personnel

The software workplace has changed dramatically over the past decade but civil service and military personnel policies have not adequately reflected these changes. For personnel with the critical skill mixes required for the development, maintenance and evaluation of software, the DoD is becoming less competitive. As a result, the DoD is increasingly less effective in technical management areas and in solving complex technical problems.

**REQUIRED ACTIONS:**

**4-A Define career paths and salary incentives for all civilian software professionals. Broaden *the career paths of those civilian software professionals* above the GS/GM-15 level.**
**OPR: OASD(FM&P) with support from DoD components**
**Estimated time to obtain Office of Personnel Management approval of new career paths: 24 months**
**Estimated cost: No direct costs**
**Priority: 1**

**4-B Define career paths and salary incentives for military software professionals up to and including the general flag rank.**
**OPR: OASD(FM&P), with support from the Military Departments**
**Estimated time to obtain agreement from the services on broadened career path to flag rank and/or service plans for incentives: 30 months**
**Estimated cost: No direct costs**
**Priority: 1**

## 4.2 GOAL: Improve Education And Training

Improving DoD software education and training programs is critical for two reasons. First, software affects almost everyone's ability to successfully perform his/her job. Second, the rapid changes in software technology and management practices often results in the obsolescence of technical skills.

Modern software engineering consists of a combination of technical and managerial skills. Most software professionals have entered the field via the technical route and have not had the opportunity to pursue the managerial aspects of software engineering. Individuals who have entered the field via a non-technical background have an enormous difficulty in understanding the technical complexity of large systems and in communicating with the technical experts. However, the field is rapidly advancing, with new concepts and technologies continually emerging that must be understood by both management and technical personnel if they are to be effectively included in DoD systems. This situation can only be improved through the aggressive application of professional level education and training.

With software as the focus of functionality and flexibility of the complex and critical systems developed by the DoD, there exists a need to raise the level of professionalism for the acquisition, management, development and post deployment support of these systems. DoD should strive to formalize the software profession.

**REQUIRED ACTIONS:**

**4-C Develop and implement Service software training programs that include provisions for post graduate software engineering education for DoD employees on a competitive basis. These programs should be centrally funded in the Services for continued application.**

**OPR: Military Departments**
**Estimated time to accomplish: 12 months for plans then continuous**
**Estimated cost: $2M per year**
**Priority: 1**

**4-D Develop software awareness course for all Senior Executive Service and General/Flag level officers and a software acquisition management course for those executives involved in the acquisition process. This could be based on similar programs such as the current Air Force Bold Stroke program and the Navy's Executive Symposium on Information Technology. The courses should range from 3 to 5 days in order to include the significant software issues and technology.**

**OPR: The National Defense University, with support from the OUSD(A) Acquisition Training and Career Development Policy Office**
**Estimated time to accomplish: 12 months**
**Estimated cost: $300K**
**Priority: 2**

**4-E Coordinate efforts of the Military Department schools (Service academies and postgraduate institutions), in conjunction with academia and the Software Engineering Institute, to develop accredited software engineering programs that address DoD needs.**

**OPR: OUSD(A) Acquisition, Training and Career Development Policy Office**
**Estimated time to accomplish: 24 months**
**Estimated cost: $300K per year**
**Priority: 2**

**4-F Develop a DoD program which allows software professionals to attend postgraduate programs in return for continuing to work for DoD for a specified length of time. This program should be targeted for recruitment of entry level college graduates as well as junior professionals already working. The program could be modeled on the Uniform**

**Medical School program currently in force to attract doctors. The goal is to attract the highest quality professionals into the pool of software professionals.**

**OPR: TBD**
**Estimated time to accomplish: 12 months for program followed by annual awards**
**Estimated cost: $50K for first year; $500K for annual scholarships**
**Priority: 2**

**4-G Coordinate efforts of the DoD Joint Service schools (National Defense University, Defense Systems Management College, Industrial College of the Armed Forces) to integrate software acquisition and development programs into existing courses.**

**OPR: OUSD(A) Acquisition, Training and Career Development Policy Office**
**Estimated time to accomplish: Continuous**
**Estimated costs: No direct costs**
**Priority: 3**

**4-H Establish mandatory software engineering educational requirements for all DoD technical and contractual personnel involved in the acquisition process. Education requirements (including on the job training and continuing education) should be tailored to the specific job category identified.**

**OPR: OUSD(A) Acquisition, Training and Career Development Policy Office**
**Estimated time to accomplish: 24 months**
**Estimated costs: No direct costs**
**Priority: 3**

# 5. SOFTWARE TECHNOLOGY BASE AND TRANSITION

**ISSUE:** *The current management, funding, and transition of the software technology base are insufficient.*

The maintenance of a strong technology base entails more than simply sustaining the research activity. It also requires the brokering of technology transition relationships, the advancement of an infrastructure for engineering and prototyping, and the fostering of an active and independent research community. One of the major reasons for the U.S. strength in technology is the strength of the research community and the means by which innovation in this community translates into products in the marketplace and in Defense systems. The effectiveness of the DoD software technology base can be significantly strengthened by (1) improving its management; (2) increasing its funding; and (3) accelerating technology transition.

## 5.1 GOAL: Improve Management Of The DoD Software Technology Base

The technology base investment has yielded very significant results when effectively managed. However, technology base programs sometimes focus on topics that are excessively near-term and constrained, that are irrelevant to DoD needs, or that do not strengthen DoD's position vis-a-vis the producers from whom it must acquire software and systems.

Program managers for technology base programs must have scientific knowledge, maturity of technical judgement, an effective understanding of contracting and acquisition principles, and an understanding of the means to manage for accomplishment in the technology base community. Because of the abstract nature of the scientific results produced, software research places particular demands on program management skills.

Effective technology base management strategy has proven to have impact far in excess of the DoD investment. Successful technology base investments are generally based on a principled investment strategy, even if breakthroughs are often serendipitous. The principles upon which this investment strategy is based include the following:

a. Use the software technology base to promote the development of open systems architectures. Technology base investment and acquisition strategy should provide incentives to industry to create solutions that enable customer flexibility and that reduce customer adoption risk. The DoD can, as a customer, use the software technology base activity to help foster open architecture approaches that can lead to standards that are accepted commercially and in defense.

b. Maintain a mixed strategy in the technology base. Excessively tight coordination among basic research sponsors in the government can result in a stifling of creativity and diversity in new ideas explored. In areas of high risk, several approaches may be pursued that may not be intellectually consistent, but that provide coverage over the range of possible outcomes.

c. Foster software technology to support hardware innovation. Software technology is subject to periodic major hardware innovations, such as the shift that occurred from batch computing to timesharing systems, then to personal computing, then to networked workstations, and now to heterogeneous distributed computing with workstations and servers. DoD must avoid surprise and be able to support these innovations. The continual succession of major hardware shifts reduces incentive for industry to invest in long term software approaches unless costs and risks can be assessed and controlled.

d. Attend to technology base human resources needs. Excessive volatility of funding can often result in the disbanding of strong research groups or in the migration of university researchers to industry, where they have less impact on producing the next generation of researchers, technical leaders, and educators.

e. Simplify the 6.1/6.2 contracting process by providing an efficient fast channel. Many researchers and research institutions are discouraged from working with DoD because of procedural difficulties, perceived and real, associated with initiating research contracts.

f. Keep the Research and Development (R&D) infrastructure current. Equipment and research facility support should be provided to researchers to enable them to remain current with the rapid pace of technological change.

g. Keep a long term focus. Long term investment is not the same as exploratory investment. It is often expedient and necessary for research program managers to redirect technology base activity to satisfy nearer term needs, but the downstream costs should be recognized.

h. Coordinate R&D investment strategy. Program managers of research programs in DoD should coordinate with potential users of research results and with program managers in related research areas before committing to research investment plans.

i. Recognize the stages of research maturity. Program managers responsible for the software technology base must take explicit steps to limit adoption risk as R&D results mature.

**REQUIRED ACTIONS:**

**5-A Use the above management principles as a guide to the performance evaluations for software technology base program managers.**

**OPR: OUSD(A)**
**Estimated time to accomplish: Continuous**
**Estimated cost: No direct costs**
**Priority: 1**

## 5.2 GOAL: Increase The Software Technology Base Investment

DoD's software problems will not be solved purely via policies and standards. An integrated DoD software strategy involving both software management and technology initiatives will make a much larger difference in resolving DoD's current and future software problems.

Numerous studies have recommended significant increases in DoD's investment in software technology research. (See Annex E.) The commercial software marketplace is often decoupled from many central DoD software concerns, such as embedded real-time software, Ada, security, and ultrareliability. Thus DoD cannot count on commercial technology to solve all of its software problems. On the other hand, an active DoD software technology strategy emphasizing commercialization and open interfaces can incentivize commercial software organizations to build DoD-critical capabilities into commercial software products.

This Master Plan has deferred the inclusion of a detailed DoD Software Technology Plan in order to decouple the approval cycle of urgent software management recommendations from the approval cycle for a major software technology investment program. The following list identifies possible topics to be addressed in the development of a DoD Software Technology Plan.

a. Software engineering environment frameworks. These are central to the integration of technology capabilities and the stimulation of commercial software tools responsive to DoD needs.

b. Software engineering tools, including requirements, design, code, instrumentation and analysis, test, configuration management, and post-deployment support tools.

c. Prototyping tools and their underlying prototyping support capabilities to support requirements engineering and design.

d. Capabilities for classification, retrieval, and evaluation of reusable software assets, including code components, interface definitions, test cases, requirements specifications fragments, etc.

e. Domain-specific software architectures, application generators, and domain-specific computational models. Opportunities exist in domains such as automatic target recognition, avionics, navigation, $C^3I$, and simulation and planning, as well as infrastructure areas such as real-time kernels, image processing, and signal processing.

f. Software re-engineering. Apply or retrofit modern software technology (e.g., decompilers, code analyzers, testing aids, configuration management aids, Ada transition aids) to DoD's huge inventory of antiquated software.

g. Management tools, including metrics and cost estimation. Candidates include group coordination and decision aids, knowledge-based software risk management aids, hypermedia and software visualization technology, gaming aids for training software managers, and automated support of modern software process models.

h. Ultrareliable and secure software.

i. Distributed and parallel software. Applications include large scientific and engineering modeling, embedded real-time applications, and AIS systems.

j. Scalable Artificial Intelligence (AI) capabilities, interoperable knowledge base services, interoperability between AI services and conventional software services, and verification and validation for AI applications.

k. Systems software, including support for security, ultrareliability, and real-time.

l. Computer science base critical to addressing future DoD needs in software reliability, security, parallelism, and distributed real-time.

m. Technology transition support, including shadow projects, mid-life re-engineering, and prototyping.

**REQUIRED ACTIONS:**

**5-B Develop the DoD Software Technology Plan and take appropriate action to obtain the required additional funding. The Plan will be implemented by the Services and Agencies.**
**OPR: OUSD(A)**
**Estimated time to accomplish: 6 months**
**Estimated cost: No direct costs**
**Priority: 1**

## 5.3 GOAL: Accelerate Technology Transition

Technology transition acceleration involves much more than just shortening the process from DoD basic research to operational systems developments. Technology users (consumers), technology suppliers (producers), and the technology transition infrastructure must be considered when making improvements. Software technology comes from several sources: research, DoD mission systems, DoD support systems, other agencies, and the commercial/industrial marketplace.

The following set of issues must be addressed in order to enhance successful technology transition:

a. Technology transition incentives for consumers. Inhibitors to transition include: (1) extra up-front effort to assimilate new technology; (2) risk of using new technology; (3) contract selections based excessively on cost and schedule rather than life-cycle quality and productivity; and (4) rights-in-data clauses requiring unlimited rights to software technology used to develop systems. Data rights provisions must enable both controllable evolution and appropriate commercialization by developers.

b. Technology transition incentives for suppliers. Inhibitors include: (1) inflexible rights-in-data clauses for vendors; and (2) university promotion criteria that emphasize publication.

c. Standards and flexibility. Inhibitors include lack of interface or modularity standards. On the other hand, overly specific standards can inhibit downstream transition.

d. Transition support planned for post deployment. Inhibitors include: (1) maintenance contracts that create disincentives; (2) inadequate change coordination across interoperating systems; (3) acquisition of commercial packages without provision for tailoring; (4) development shortcuts; and (5) shortfalls in "nonstop" hardware-software operating capabilities for operational systems.

e. Consumers' readiness for technology transition. Inhibitors include: (1) difficulty to jump to much higher level technology; and (2) organizational reluctance to accept risks and changes.

f. Technology supplier's maturity. Inhibitors include: (1) failure to provide seed funds to reduce risks; (2) failure to identify consumers; and (3) failure to demonstrate need for the new technology.

g. Technology maturity. Inhibitors include: (1) immaturity of new-technology prototypes; and (2) failure to address issues of robustness and scale.

Technology transition can be accelerated by sponsoring technology initiatives to support technology transition and developing a process for assessing and monitoring technology transition. Contracting, personnel, and life-cycle issues associated with software technology transition are addressed in other chapters.

The following list identifies possible technology initiatives in support of technology transition which may be addressed in the DoD Software Technology Plan.

a. Promote shadow projects. Shadowing an ongoing project enables direct funding of risk while providing realistic technical context and realistic inputs for a development. This allows technology to be experimentally transitioned and executed with the result compared to the baseline development effort.

b. Promote standard open interfaces. Standard open interfaces and domain-specific software architectures facilitate transition of improved technology and reuse. These efforts provide a basis for development of software repositories and catalogs.

c. Institute software mid-life cost-effectiveness reviews and attendant upgrades. These techniques can facilitate transitioning of modern technology such as COTS and Ada into existing older systems.

d. Develop catalogs and repositories for software architectures, interfaces, components, and other assets. Application specific catalogs will enable technology identification, selection, and comparison in terms of problem features. Repository management schemes need to be developed for charging users, allocating proceeds, funding productization, and protecting proprietary interests. Technology suppliers need incentives to provide product and interface data for use in repositories and catalogs. Repositories can enable cooperation among producers and consumers in establishing common architectures, interfaces, and validation mechanisms.

e. Develop an information clearinghouse to disseminate software technology evaluation and information. Examples include the Ada Information Clearinghouse and the Software Technology Support Center, which provide information regarding compiler validation and evaluation, performance, newsletters, electronic mail bulletin boards, focused supplier-consumer workshops, and other pertinent information.

f. Develop a process for assessing and monitoring technology transition. The DARPA-sponsored Software Engineering Institute (SEI) has developed a Process Maturity Assessment for rating the software development process and practices within a DoD or contractor organization. Similar checklists and process assessment techniques are needed to evaluate and improve technology transition practices. Elements of a transition assessment could include consideration of incentive structures for technology producers and consumers, evidence of workable risk and cost assessments for technology consumers, validation mechanisms for technology producers, and evidence of life cycle impact assessment for near-term technology selections.

**REQUIRED ACTIONS:**

**5-C Develop a plan and implementation strategy to establish, coordinate, and sustain DoD application software repositories, catalogs, and application-specific software architectures. The plan should address definition of effectiveness metrics for repositories and catalogs.**

**OPR: DARPA and DoD components**
**Estimated time to accomplish: 12 months**
**Estimated cost: $ 1M**
**Priority: 2**

**5-D Establish a software information clearinghouse.**

**OPR: OUSD(A)**
**Estimated time to accomplish: 12 months to establish**
**Estimated cost: $500K per year to maintain**
**Priority: 3**

**5-E Develop a process for assessing and monitoring the technology transition capability of DoD organizations.**

**OPR: DARPA and DoD components**
**Estimated time to accomplish: 24 months**
**Estimated cost: $ 1M per year**
**Priority: 3**

# 6. ACTION SUMMARY, PRIORITY, FUNDING, AND SCHEDULE

This chapter provides a summary, priority, funding and schedule for each of the required actions identified in Chapters 2 through 5.

Table 6-1 lists the priority assigned to each required action. Actions are prioritized on a scale of #1 to #3 with #1 being most important. Actions are identified by the number/letter pair assigned in Chapters 2 through 5 and by a brief phrase, summarizing the action. Because it is not possible to capture the full meaning of each action in a single phrase, the reader is advised to refer to the full text associated with each action, provided in Chapters 2 through 5.

The action determined to be most significant in the implementation of this DoD Software Master Plan is the designation of an office by the Deputy Secretary of Defense (Action #2-A) to serve as a focal point within the DoD for software. This office should have primary responsibility for identifying, managing, integrating and implementing software acquisition and life cycle management policy. Table 6.1 also includes the schedules associated with all actions. Schedules have been based upon a start date of fiscal year 1991. Table 6-1 also provides a financial summary of the estimated DoD funds required for completion of the actions identified in Chapters 2 through 5.

It is important to note that the funding profile shown in Table 6-1 does not represent the total additional DoD funding that is required to address the software problems within the Department. No attempt has been made to provide funding allocations for those actions that are primarily based upon internal DoD activities such as organizational changes and coordination efforts, for which there are no direct costs. The total amount of funding required is expected to be significantly higher, particularly with efforts such as the scaling up of the software technology base. The OUSD(A) should be responsible for updating these schedules and funding profiles accordingly.

## Table 6-1 Action Summary, Prioritization, Schedule, and Funding

| Action Number and Summary | Pri. | FY91 | FY92 | FY93 | FY94 | FY95 |
|---|---|---|---|---|---|---|
| 2-A Designate office as SW focal point | 1 | | | | | |
| 2-B Ensure SW addressed within DAB structure | 1 | | | | | |
| 2-C Ensure TQM techniques used for SW | 2 | 1000K | 1000K | 1000K | 1000K | 1000K |
| 2-D Define SW risk management framework | 2 | 100K | | | | |
| 2-E Establish metric tool "Consumer's Union" | 3 | 1000K | 1000K | 1000K | 1000K | 1000K |
| 2-F Propose technology insertion projects | 3 | | | | | |
| 2-G Review acq. & contracting strategies for SW issues | 1 | | | | | |
| 2-H Initiate cases with FAR Council on SW issues | 1 | | | | | |
| 3-A Consolidate SW directives/policies/guidance | 1 | | | | | |
| 3-B Consolidate Ada policy and oversight | 1 | | | | | |
| 3-C Establish system policies to address SW support | 1 | | | | | |
| 3-D Review system acq. strategies for SW issues | 2 | | | | | |
| 3-E Update software and related standards | 2 | | | | | |
| 3-F Revise software export/import policy | 3 | | | | | |
| 4-A Define civilian SW career paths and salary incentives | 1 | | | | | |
| 4-B Define military SW career path to General/Flag rank | 1 | | | | | |
| 4-C Dev. service SW training plans leading to adv. degree | 1 | 2000K | 2000K | 2000K | 2000K | 2000K |
| 4-D Develop SW awareness and SW acq. mgt. courses | 2 | 300K | | | | |
| 4-E Develop accredited SE programs | 2 | 300K | 300K | | | |
| 4-F Develop DoD SE scholarship program | 2 | 50K | 500K | 500K | 500K | 500K |
| 4-G Integrate SW programs into DoD Joint Service Schools | 3 | | | | | |
| 4-H Establish SE educational requirements | 3 | | | | | |
| 5-A Use key principles to evaluate tech base managers | 1 | | | | | |
| 5-B Develop SW Technology Plan | 1 | | | | | |
| 5-C Develop plan for DoD SW repositories | 2 | 1000K | | | | |
| 5-D Establish SW Information Clearinghouse | 3 | 500K | 500K | 500K | 500K | 500K |
| 5-E Develop tech transition assessment process | 3 | 1000K | 1000K | | | |

## REFERENCES

[BETTI89] Betti, John A., Under Secretary of Defnse for Acquisition, "The Acquisition Process", *Defense 89*, November/December, pp. 8-12.

[DoD89] *The Department of Defense Critical Technologies Plan*, for the Committees on Armed Services, United States Congress, March 15, 1989.

[DSB87] *Report of the Defense Science Board Task Force on Military Software*, September 1987.

[HOUSE89] *Bugs in the Program: Problems in Federal Government Computer Software Development and Regulation*, Committee on Science, Space, and Technology, U.S. House of Representatives.

[OSD89] *DEFENSE MANAGEMENT Report to the President*, by Secretary of Defense Dick Cheney, July, 1989.

[Tenenbaum87] Tenenbaum, J., *The Military Computing Crisis: The Search for a Solution: Summary and Investment Opinion*, Salamon Brothers, Inc., 22 September 1987.

[ZRAKET88] *Report of Workshop on Military Software*, 1 July 1988, Charles A. Zraket, Chair.

## ACRONYMS

| | |
|---|---|
| AIS | Automated Information Systems |
| $C^3I$ | Command, Control, Communications, and Intelligence |
| COTS | Commercial Off-The-Shelf |
| DAB | Defense Acquisition Board |
| DARPA | Defense Advanced Research Project Agency |
| DMR | Defense Management Report |
| DoD | Department of Defense |
| DOD-STD | Department of Defense Standard |
| FAR | Federal Acquisition Regulation |
| MIL-STD | Military Standard |
| ODUSD(I&IP) | Office of the Deputy Under Secretary of Defense (Industrial and International Programs) |
| OASD(FM&P) | Office of the Assistant Secretary of Defense (Force Management and Personnel) |
| OPR | Office of Primary Responsiblity |
| OSD | Office of the Secretary of Defense |
| OUSD(A) | Office of the Under Secretary of Defense (Acquisition) |
| PDSS | Post Deployment Software Support |
| R&D | Research and Development |
| S&T | Science and Technology |